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U. S. Geographical and Geological Survey of the Rocky Mountain Region.

Report. 1877.

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REPORT

ON THE

GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE ROCKY MOUNTAIN REGION,

BY

J. W. POWELL.

DEPARTMENT OF THE INTERIOR,
U. S. GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE
ROCKY MOUNTAIN REGION,
Washington, D. C., November 25, 1877.

SIR: I have the honor to submit herewith a brief abstract of the operations of the Survey under my direction.

The first part relates to the field-operations for the fiscal year ending June 30, 1877. This occurs from the fact that my parties did not arrive from the field until about the 1st of January, 1877; too late to prepare a statement for the last annual report of the Secretary.

FIELD SEASON OF 1876.

As soon as the appropriation for the fiscal year of 1876–'77 could be used, the surveying corps left Washington and proceeded to the rendezvous camp at Gunnison, Utah, where the field-parties were organized, under the general superintendence of Prof. A. H. Thompson, geographer of the expedition. While *en route* they were joined by Capt. Clarence E. Dutton, of the Ordnance Department U. S. A., who had been assigned for duty with this Survey by the Secretary of War, and directed to make an examination of the immense fields of igneous rocks in Southeastern Utah.

The field organization as finally completed, differed somewhat from that of previous years, the geographic and geological work being assigned to separate parties, each practically independent in all movements though working under the same general plan and within the same territorial limits. It is believed that better results can be, and have been secured by this separation of distinct branches of the survey than by the old method of attaching a geologist to a geographic party or a geographer to a geological party.

Five parties were organized: one under Prof. A. H. Thompson to continue the triangulation; one topographic party under Mr. Walter H. Graves, another under Mr. John H. Renshawe; one geological party, under Mr. G. K. Gilbert, another under Capt. C. E. Dutton.

TRIANGULATION BY PROFESSOR THOMPSON.

The party under Professor Thompson continued the expansion of the primary triangulation resting on the base lines measured in preceding years at Kanab and Gunnison, Utah. The area embraced in this season's work amounts to about 10,000 square miles.

TOPOGRAPHIC WORK BY MR. GRAVES.

Topographic party No. 1, in charge of Mr. Graves, extended the secondary triangulation over an area of 6,000 square miles, lying between

the Wasatch Mountains on the west and the Green and Colorado Rivers on the east. Mr. Graves also made a complete plane-table sketch of the country surveyed, which, taken in connection with his angles for locations and perspective profile sketches, will enable him to construct a map of his district on a scale of 4 miles to the inch. The principal topographic characteristics of this region are long lines of unscalable cliffs, the escarped edges of terraced plateaus, of which the country is composed, and deep, narrow cañons, with vertical walls, both presenting well-nigh impassable barriers to travel.

The only considerable bodies of irrigable lands found are along the valleys of the Green and San Rafael Rivers. The only timber lands are on the Sevier plateaus at an elevation from 8,000 to 11,500 feet.

TOPOGRAPHIC WORK BY MR. RENSHAWE.

The work of topographic party No. 2, under Mr. Renshawe, was confined to Southwestern Utah and Southeastern Nevada, one of the most rugged and barren sections in the Great Basin. The methods of survey were the same as adopted by party No. 1, except that perspective profile sketches were made by the aid of the orograph, a newly designed instrument that promises to be of great use in topographic surveying. The work of Mr. Renshawe and his assistant, Mr. O. D. Wheeler, was extended over about 4,000 square miles. In all this area no considerable bodies of irrigable lands are found; probably not one-half of one per cent. possessing any value except for pasturage.

TOPOGRAPHIC WORK BY MR. GILBERT.

A topographic survey of the Henry Mountains was made in 1875, and a map constructed on a scale of 4 miles to the inch; but this being thought too small a scale to admit of correct representation of the details of the geology, Mr. Gilbert in addition to his geological work made a more detailed survey of the topography, carrying a complete system of secondary triangulation and a connected plane-table sketch over more than 1,000 square miles. The data collected are sufficient to make a topographic map of the Henry Mountains on a scale of 2 miles to the inch, or $\frac{1}{63000}$.

DIVISION OF THE AREA INTO DISTRICTS FOR MAPPING PURPOSES.

The Rocky Mountain Region of the United States (not including Alaska), or that portion west of the meridian of 99° 30′, was by a former Secretary of the Interior divided into districts for surveying and mapping purposes and these districts numbered. The area of each district is $2\frac{1}{2}$ degrees in longitude and $1\frac{1}{4}$ degrees in latitude. The region of country surveyed by the parties under my direction is embraced in districts numbered 75, 85, 86, 95, 96, 104, and 105 (see accompanying map), the first five lying directly west of the region in which Dr. Hayden was engaged, while districts 104 and 105 lie immediately south of the other districts in which my own parties have been at work. During the earlier part of the work, before these districts were established by the Department, the operations of the Survey extended in an oblique direction from northeast to southwest along the general course of the Green and Colorado Rivers, through the districts above designated, but the work was in such condition that no one district was complete. During the season my parties were engaged in extending the survey over the unsurveyed fractional districts so that final and complete maps of each could be constructed.

METHODS AND OBJECTS OF SURVEY.

The methods of survey during the season were in part the same as those employed the previous year, modified to some extent as experience had suggested. In addition to the determination of geodetic positions and general geographic features, the system of classifying the lands inaugurated in former years was continued, the object of this classification being to determine the extent and position of the irrigable lands, timber lands, mineral lands, and waste lands; the latter being composed of rugged mountains and desert plains. The practical importance of this classification if carefully made, is great, not only in presenting the information desirable to those who wish to settle in the country, but also in the collection of facts necessary to intelligent legislation concerning these lands.

In the region embraced in this survey a very small portion of the country can be redeemed by irrigation for agriculture, and no part of it can be cultivated without. It appears from the reports that less than one-half of one per cent. can be thus made available. Especial care was given to the determination of the extent of such lands so as to exhibit their position on the maps. These irrigable lands and timber lands, together with some small districts of coal bearing lands are the only portions of the country that should be surveyed into townships and sections. Having in view economy and convenience in the linear surveys of this district, the geodetic points of the general geographic survey under my direction were carefully marked, that they might thereafter be used as datum-points by the officers of the General Land Office.

Extensive coal fields exist in the region surveyed, but as in many other parts of the world they are of practical value at comparatively few places. The general characteristics of these coal fields have been the subject of much investigation and some very interesting and valuable results have been reached; these will appear in the final reports. The quantity of available coal is practically inexhaustible and the mines that can be economically worked are of great number.

In the Uinta Mountains silver and copper mines have been discovered and worked by private parties. The extent of these silver and copper bearing rocks was determined, but their value can be established only by extensive working.

GEOLOGICAL WORK BY MR. GILBERT.

Mr. G. K. Gilbert devoted much of his time to the study of the structure of the Henry Mountains, of which enough had been learned in the preceding season to warrant the belief that they embodied a type of eruption hitherto unknown. The attention given to them has been amply repaid by the elucidation of the manner of their constitution. They are volcanic, but their lavas instead of finding vent at the surface of the ground and piling up conical mountains thereupon in the usual manner ceased to rise while still several thousands of feet underground, and lifted the superincumbent strata so as to make for themselves deep-seated subterranean reservoirs within which they congealed. Over each of these reservoirs the strata were arched, and a hill or mountain was lifted equal in magnitude to that which would have been formed if the lava had risen to the surface; but the material of the hill was sandstone and shale instead of hard volcanic rock. Subsequent erosion has carried away more or less completely the arching strata, and laid bare many of the intrusive masses. It has revealed also a system of reticulating dikes which go forth in all directions from the main masses, intersecting

the sedimentary rocks. The lava masses, the dikes, and those portions of shale and sandstone which have been metamorphosed by contact with the molten rock, are harder than the unaltered sedimentary strata which surround them, and yield to the agents of erosion more slowly. The wash of rain and streams by which the face of the surrounding country has been degraded has been resisted by these hard cores, and in virtue of their obduracy we have the Henry Mountains. The deposits of lava are not all in juxtaposition but are scattered in clusters, and each cluster has created a mountain. Mount Ellen consists of a score of individual lava masses; Mount Pennell and Mount Hillers each of one principal mass accompanied by several of minor importance; Mount Holmes of two masses; Mount Ellsworth of a single one, with many dikes and sheets. Each of the mountains is individual, topographically as well as structurally, and together they constitute a group of mountains, not a range.

Mr. Gilbert also made a valuable addition to our knowledge of structural geology by tracing through Southern Utah the unconformity of the Tertiary upon the Cretaceous, which had previously been observed in other portions of the Plateau Province. He found an unconformity of dip amounting in some places to sixty degrees, and brought back sketches and photographs showing actual superposition and contact.

Before commencing the main work of the season, Mr. Gilbert made an excursion in search of the outlet of Lake Bonneville, the great fossil lake of Utah. During an epoch which was probably coincident with the Glacial epoch, the broad interior basin of Utah was covered by a great lake which overflowed its rim and sent an outlet to the ocean by way of the Columbia River. When the climate became gradually warmer and drier, the evaporation grew greater and the rainfall grew less, until finally the overflow ceased and the lake began to dry away and shrink within its shores; to-day only Great Salt Lake, Utah Lake, and Sevier Lake remain, but high up on the mountain is carved the Bonneville Beach, a permanent record of the old flood-tide. The search for the point of outlet was successful, and it was found at the north end of Cache Valley, a few miles beyond the boundary of Utah, in the Territory of Idaho. The bed of the outflowing stream was traced for a number of miles. The beach lines were seen to run quite to the pass through which the channel was cut, but beyond, on the side of the drainage of the Columbia, no trace of them could be seen.

Of no less interest was the discovery of a recent orographic movement at the western base of the Wasatch Range. A great fault runs along that base—one of the faults by which the mountains were produced. The block of the earth's crust which lies to the westward of the fault plane was dropped down, or the block which lies to the eastward was lifted up, and from the eastward block subsequent erosion has carved the range. Along the plane of ancient movement there has been a recent movement. The mountain has risen a little higher or the valley floor has dropped a little lower, and this so recently that the Bonneville flood is ancient in comparison.

GEOLOGICAL WORK BY CAPT. DUTTON.

Capt. C. E. Dutton resumed his study of the large area of igneous rocks in Southern Utah, in the vicinity of the Sevier River, and brought back additional information which he purposes employing in the preparation of a monograph of the entire tract. He worked out the structure of the component features and the approximate area of the eruptions, and began the classification of the various lithologic members. The older outbreaks appear to be of early Tertiary Age (Eocene), and

to have been nearly continuous through a long period. The volcanic beds thus formed were subsequently traversed by great faults, and tables were uplifted with deep valleys between them, the structure thus produced conforming to the general type prevalent throughout the plateau country. The degradation of these long lofty tables gave rise to conglomerate beds of great extent and thickness, which are composed entirely of volcanic materials. Captain Dutton has compared the details and arrangement of these conglomerates with the alluvial beds now accumulating in great volume in the valleys out of the waste of the adjoining tables, and finds an agreement so close that he ascribes the same mode of origin to both. He also finds considerable metamorphism, not only in the underlying sedimentary beds (early Tertiary), but in the supposed conglomerate; and he thinks it must have occurred comparatively near the surface. The greater portion by far of the erupted rocks he classes as trachytes and trachydolerites. The rhyolitic varieties are of very limited occurrence, being found only in the vicinity of the Beaver or Tushar Range. In the southwestern part of the field (near Panguitch) extensive fields of basalt are found. Captain Dutton distinguishes two ages of the basalt: one prior to the development of the present structural features of the region, the other subsequent to it; the former being more properly dolerite or anamesite, the latter typical basalt.

ETHNOGRAPHIC WORK.

Under instructions from the Interior Department, my parties were also engaged in general ethnographic work in the Rocky Mountain Region. One of the special items in these instructions was the classification of Indian tribes, such classification being not only of scientific interest but of great importance in the administration of Indian affairs. For the eastern portion of the United States this work had been accomplished, first by the unofficial labors of the Hon. Albert Gallatin, and subsequently by the Hon. Henry R. Schoolcraft as an officer of the government; and some additions had been made by various persons for scientific purposes. This work was renewed by myself and pushed with all the energy possible with the funds at my command, and a large amount of material has been collected by myself and by members of my corps, and by residents in and travelers through the country. In addition to this a large amount had been collected by the Smithsonian Institution through various channels. That institution placed all this matter in my hands to be combined with my own collections.

PHOTOGRAPHIC WORK BY MR. HILLERS.

During a part of the season the photographer, Mr. J. K. Hillers, was attached to Prof. Thompson's party, making views for the illustration of the geological structure. Subsequently, in charge of a small party, he visited certain points in Northern Arizona to obtain some views in that region that were needed for the same purpose. He returned with a large amount of graphic material of great value.

BOTANY.

Mr. L. F. Ward, the botanist of the corps, assisted by several gentlemen of scientific ability in this department, was engaged during the entire year in the preparation of a "Report on the Botany of the Valley of the Colorado," which is now nearly ready for publication.

OFFICE WORK OF 1876–'77.

On the arrival of the parties from the field early last winter, work was promptly organized and pushed with all possible vigor through the winter and spring.

TOPOGRAPHIC WORK.

The first work of the topographers was the preparation of preliminary maps of the region surveyed during the season. These were constructed by making tracings of the plane-table sheets. In one month these maps were ready. In the mean time Professor Thompson and his mathematical assistants were engaged in computing the triangles and making the necessary adjustments for closure and determining the azimuths, latitudes, longitudes, and altitudes necessary for the construction of the final atlas sheets.

After completing the preliminary maps and following closely the progress of the mathematic work, the topographers engaged in the preparation of the final maps, and by the close of the office season, early in May, the whole work was made ready for the engraver.

The comparison of these final maps with the preliminary maps above-mentioned was a rigorous test of the accuracy with which the topographers had done their work in the field and of the value of the methods and instruments employed. This was especially desirable from the fact that new methods and instruments were used, and while theoretically they appeared to be valuable, the test of experience was necessary for a final determination of their usefulness. The result exhibited the fact that the topographers could take the field with sheets upon which the primary triangulation was plotted and return with maps that would need so little readjustment after the final computations were made that it was scarcely perceptible on the scale adopted for publication. And it was further demonstrated that a topographer in one field-season could extend his work over an area of about five thousand square miles, and with all the accuracy necessary for the scale adopted by the Interior Department for the physical atlas of the Rocky Mountain Region, *i. e.*, a scale of four miles to the inch.

As previously mentioned, this geographic work was under the immediate charge of Prof. A. H. Thompson, and his work is not more highly commended than it deserves in making the above statement.

INSTRUMENTS.

The base-measuring apparatus has been described in a previous report.

The *theodolite* used in the triangulation is of a new pattern, embracing a number of improvements demanded by the character of the work. So far as possible the number of parts has been reduced by casting in a single piece parts that are usually combined by screws. In this manner the liability to derangement incident to the vicissitudes of mountain work is greatly reduced. The telescope has been enlarged, as compared with the graduated circle, so as to make its defining power bear a greater proportion than usual to the refinement of graduation. The object-glass has an aperture of two inches and a focal length of twenty. The horizontal circle is ten inches in diameter, and reads by double verniers to five seconds of arc. The vertical circle is five inches in diameter and reads to one minute. The instrument also embraces other improvements designed to secure greater stability, with ease and rapidity in manipulation.

In the topographic work the gradientor and sketch book are being superseded by the plane-table and the orograph. The *plane-table* in use is of a pattern designed by Professor Thompson especially for work of this character. The drawing board is made of a series of slats firmly fixed to canvas in such manner that it can be rolled into small compass for transportation; but when unrolled for work it is so secured by cross-pieces and screws that great stability is attained. When in use it is fastened to the platen of the orograph. The position of important features in the topography are fixed with an alidade by the usual methods of intersection and resection. Details are placed directly upon the map while they are still under the eye of the topographer, and much of the labor and uncertainty of description by notes is avoided. The sketches produced on the plane-table are actual maps and not mere map material. They need only to be adjusted in conformity with the triangulation; and experience has shown that when the work of triangulation precedes that of topography but slight adjustment is necessary.

The *orograph* is a new instrument in topographic surveying, adapted to the requirements of this work by Professor Thompson. It consists essentially of a telescope erected above a platen or drawing-board, on which the movements of its optical axis are recorded. The telescope rotates about a vertical and about a horizontal axis, similarly to the telescope of a theodolite, and is connected by simple mechanism with a pencil which rests on a sheet of paper attached to the platen. When the topographer moves the telescope so as to carry its optical axis over the profiles of the landscape the pencil traces a sketch of the same. This sketch, being mechanically produced, is susceptible of measurement, and is a definite and authoritative record of the angular relations of the objects sketched. The instrument is also furnished with a graduated circle on which horizontal angles may be read to the nearest half minute, and this circle is used for the secondary triangulation. The orograph and plane-table are used conjointly, and their results furnish data for the production of contour maps. It is believed that by their introduction the quality of topographic work has been much improved without addition to its cost.

Mr. Gilbert has made a critical examination and discussion of the barometric observations extending through the previous years of the work, for the purpose of determining the range of error, and of detecting as far as possible the source thereof. The result of this examination tended to show that one of the principal sources of error was inaccuracy in reading and recording, and for the purpose of eliminating these, suggested a number of checks, of which the most important was the reading and recording of the two verniers of the Green barometer instead of a single one. The interval between the two verniers is of such length that their fractional readings are always different, and it is practically impossible to repeat the same error.

GEOLOGICAL WORK.

During the same time Mr. G. K. Gilbert prepared his report on the Geology of the Henry Mountains, with stereograms, diagrams, and other illustrations, and the manuscript was sent to the printer. The book is now ready for the binder.

A second report was also prepared on the volcanic plateaus of Utah, by Capt. C. E. Dutton, but it was not deemed wise to publish it until the region had been more fully investigated. This was in pursuance of plans that have been followed in all the work under my direction, viz, to publish only monographs, which shall embody the final results of all

the work it is expected to be done in any particular field; and I fully agreed with Captain Dutton that the region of his researches presented problems in structural geology worthy of a third survey.

ETHNOGRAPHIC WORK.

During the same office season the ethnographic work was more thoroughly organized, and the aid of a large number of volunteer assistants living throughout the country was secured. Mr. W. H. Dall, of the United States Coast Survey, prepared a paper on the tribes of Alaska, and edited other papers on certain tribes of Oregon and Washington Territory. He also superintended the construction of an ethnographic map to accompany his paper, including on it the latest geographic determination from all available sources. His long residence and extended scientific labors in that region peculiarly fitted him for the task, and he has made a valuable contribution both to ethnology and geography.

With the same volume was published a paper on the habits and customs of certain tribes of the State of Oregon and Washington Territory, prepared by the late Mr. George Gibbs while he was engaged in scientific work in that region for the government. The volume also contains a Niskwalli vocabulary with extended grammatic notes, the last great work of the lamented author.

In addition to the maps above mentioned and prepared by Mr. Dall, a second has been made, embracing the western portion of Washington Territory and the northern part of Oregon. The map includes the results of the latest geographic information and is colored to show the distribution of Indian tribes, chiefly from notes and maps left by Mr. Gibbs.

The Survey is indebted to the following gentlemen for valuable contributions to this volume: Gov. J. Furujelm, Lieut. E. De Meulen, Dr. Wm. F. Tolmie, and Rev. Father Mengarini.

Mr. Stephen Powers, of Ohio, who had spent several years in the study of the Indians of California, had the year before been engaged to prepare a paper on that subject. In the mean time at my request he was employed by the Bureau of Indian Affairs to travel among these tribes for the purpose of making collections of Indian arts for the International Exhibition. This afforded him opportunity of more thoroughly accomplishing his work in the preparation of the above-mentioned paper. On his return the new material was incorporated with the old, and the whole has been printed.

At our earliest knowledge of the Indians of California they were divided into small tribes speaking diverse languages and belonging to radically different stocks, and the whole subject was one of great complexity and interest. Mr. Powers has successfully unraveled the difficult problems relating to the classification and affinities of a very large number of tribes, and his account of their habits and customs is of much interest.

In the volume with his paper will be found a number of vocabularies collected by himself, Mr. George Gibbs, General George Crook, U. S. A., General W. B. Hazen, U. S. A., Lieut. Edward Ross, U. S. A., Assistant Surgeon Thomas F. Azpell, U. S. A., Mr. Ezra Williams, Mr. J. R. Bartlett, Gov. J. Furujelm, Prof. F. L. O. Roehrig, Dr. William A. Gabb, Mr. H. B. Brown, Mr. Israel S. Diehl, Dr. Oscar Loew, Mr. Albert S. Gatschet, Mr. Livingston Stone, Mr. Adam Johnson, Mr. Buckingham Smith, Padre Aroyo, Rev. Father Gregory Mengarini, Padre Juan Camelias, Hon. Horatio Hale, Mr. Alexander S. Taylor, Rev. Antonio Timmeno, and Father Bonaventure Sitjar.

The volume is accompanied by a map of the State of California, compiled from the latest official sources and colored to show the distribution of linguistic stocks.

The Rev. J. Owen Dorsey, of Maryland, has been engaged for more than a year in the preparation of a grammar and dictionary of the Ponka language. His residence among these Indians as a missionary has furnished him favorable opportunity for the necessary studies, and he has pushed forward the work with zeal and ability, his only hope of reward being a desire to make a contribution to science.

Prof. Otis T. Mason, of Columbian College, has for the past year rendered the office much assistance in the study of the history and statistics of Indian tribes.

On June 13, Brevet Lieut. Col. Garrick Mallery, U. S. A., at the request of the Secretary of the Interior, joined my corps under orders from the honorable Secretary of War, and since that time has been engaged in the study of the statistics and history of the Indians of the western portion of the United States.

In April last, Mr. A. S. Gatschet was employed as a philologist to assist in the ethnographic work of this Survey. He had previously been engaged in the study of the languages of various North American tribes. In June last at the request of this office he was employed by the Bureau of Indian Affairs to collect certain statistics relating to the Indians of Oregon and Washington Territory, and is now in the field. His scientific reports have since that time been forwarded through the honorable Commissioner of Indian Affairs to this office. His work will be included in a volume now in course of preparation.

Dr. H. C. Yarrow, U. S. A., now on duty at the Army Medical Museum, in Washington, has been engaged during the past year in the collection of material for a monograph on the customs and rites of sepulture. To aid him in this work circulars of inquiry have been widely circulated among ethnologists and other scholars throughout North America, and much material has been obtained which will greatly supplement his own extended observations and researches.

Many other gentlemen throughout the United States have rendered me valuable assistance in this department of investigation. Their labors will receive due acknowledgment at the proper time, but I must not fail to render my sincere thanks to these gentlemen, who have so cordially and efficiently co-operated with me in this work.

A small volume, entitled "Introduction to the Study of Indian Languages," has been prepared and published. This book is intended for distribution among collectors. In its preparation I have been greatly assisted by Prof. W. D. Whitney, the distinguished philologist of Yale College. To him I am indebted for that part relating to the representation of the sounds of Indian languages; a work which could not be properly performed by any other than a profound scholar in this branch.

I complete the statement of the office-work of the past season by mentioning that a tentative classification of the linguistic families of the Indians of the United States has been prepared. This has been a work of great labor, to which I have directed much of my own time, and in which I have received the assistance of several of the gentlemen above mentioned.

In pursuing these ethnographic investigations it has been the endeavor as far as possible to produce results that would be of practical value in the administration of Indian affairs, and for this purpose especial attention has been paid to vital statistics, to the discovery of linguistic affinities, the progress made by the Indians toward civilization,

and the causes and remedies for the inevitable conflict that arises from the spread of civilization over a region previously inhabited by savages. I may be allowed to express the hope that our labors in this direction will not be void of such useful results.

FIELD SEASON OF 1877.

About the middle of May last the surveying corps again took the field. This year the rendezvous camp was at Mount Pleasant, a little town in Utah about 125 miles south of Salt Lake City. Three parties were organized under the direction of Professor Thompson, one to extend the triangulation and two for topographic purposes.

In the early part of the season, the field work was somewhat delayed by reason of the late falling of snow, making it impracticable to ascend the higher mountains.

The area designated for the season work lies between 38° and 40° 30′ north latitude, and between 109° 30′ and 112° west longitude, Greenwich, and is embraced in atlas sheets 86 and 75.

TRIANGULATION BY PROFESSOR THOMPSON.

The triangulation party was under the immediate charge of Professor Thompson, assisted by Mr. O. D. Wheeler. In the early part of the season the work was extended over a broad area west of the Green River.

On account of general rumors for a number of years concerning the hostility of the Ute Indians in the vicinity of the Sierra la Sal, on the east side of the Green and Colorado Rivers, he deemed it wise to consolidate his party with one of the topographic parties, for the purpose of visiting that region, in order that he might have a force of greater strength. For this purpose he took with him the party under Mr. Graves, and the triangulation and topography were carried on simultaneously. Events proved that the rumors were groundless.

The triangulation was extended over an area of something more than 16,000 square miles. As in previous years the work rests on the base-lines of Kanab and Gunnison and was connected on the east with the triangulation-points established by Dr. Hayden, in charge of the United States Geological Survey of the Territories, and on the north with those of Clarence King, United States Geologist in charge of the Survey of the Fortieth Parallel. The instrument used was the same as that of the former year; the triangulation-points were artificial, marked by by stone cairns and flag-staffs.

Professor Thompson also determined the amount of water flowing in the larger streams of the region.

TOPOGRAPHIC WORK BY MR. GRAVES.

The district assigned Mr. Graves for topographic work was the eastern half of atlas sheet 75 and that portion of sheet 86 lying east of the Green and Colorado Rivers—an area of about 10,000 square miles.

The most remarkable topographic feature of this region is a bold escarpment facing the south and extending from the western far beyond the eastern limit of Mr. Graves' work. This is known as the Book Cliffs. At the foot of this escarpment lies a narrow valley through which passes the only practicable route of travel between Central Utah and Western Colorado. South of the valley the whole region is cut by a labyrinth of cañons, formed by the Grand, Green, and San

Rafael Rivers and their tributaries. This region is one of the most inhospitable and inaccessible in the territory of the United States. It is characterized by extreme aridity, and some portions are cut by many narrow gorges, forming "alcove lands." In other portions are found hills of naked sands and clays—regions of bad lands. Bold cliffs, towering monuments, hills of drifting glittering sands, and deep tortuous cañons give to the landscape an appearance strange and weird.

The Book Cliffs rise to an altitude above their base of 2,000 feet, and about 8,500 feet above the sea-level, and the country from the southern crest inclines gently northward to the valleys of the White and Uinta Rivers. This gigantic terrace, called the Ta-vá-puts Plateau, is cut in twain from north to south by the profound gorges of the Green River, known as the Cañon of Desolation and Gray Cañon. The drainage of the plateau is northward from the brink of the cliffs through deep narrow cañons for many miles, but at last all these enter the Cañon of Desolation a few miles from its head. North of the Ta-vá-puts Plateau are the valleys of the White and Uinta Rivers. Nearly all the former and a large portion of the lower course of the latter are within the boundaries of Mr. Graves's work.

Over the whole district assigned to Mr. Graves he extended the secondary triangulation. Owing to the peculiar topography of the country, his stations will average about ten miles apart. He also made a connected plane-table map of the whole area, and complemented his work with orographic sketches.

In the southern portion of the area surveyed by Mr. Graves considerable bodies of irrigable lands are found along the Grand, Green, San Rafael, and Price Rivers; and in the northern part, along the Green River and in the valleys of the Uinta and White Rivers, are large tracts of excellent land, on which the waters of the streams named can be conveyed at slight cost. Mr. Graves paid especial attention to the extent and character of these lands, and to the amount of water carried by the streams.

On the Ta-vá puts Plateau are small forests of pine and fir, but generally Mr. Graves's district possesses no more timber than sufficient to meet the future local requirements of actual settlers.

TOPOGRAPHIC WORK BY MR. RENSHAWE.

The district assigned Mr. Renshawe was the western portion of atlas sheet 75, an area of about 6,000 square miles. The eastern portion of this area is a broad plateau, having an average elevation of about 9,500 feet, cut by deep valleys and drained from its very western edge toward the east by the Dirty Devil, San Rafael, Price, and Uinta Rivers. The western portion includes broad valleys, abrupt ranges of mountains, and one plateau of considerable extent. The principal valleys are the San Pete, Juab, and Uinta, all having a general northern and southern trend and an average elevation of about 5,000 feet, and all drained by the San Pete River and the streams flowing into Utah Lake. The mountain-ranges standing between the valleys are the Wasatch, rising in its highest peaks to 12,000 feet, the Cañon Range, and the Valley Range, each reaching an altitude of nearly 10,000 feet.

The plateau, which we have called Gunnison Plateau, has an area of about 750 square miles, and an average elevation of 8,000 feet. It is bounded on three sides by almost vertical walls, and is extremely rugged and difficult to traverse.

There is but little irrigable land in the eastern portion of Mr. Renshawe's district, but the broad valleys of the western portion contain

large areas of excellent lands, and the numerous streams furnish a good supply of water.

On the plateaus and mountain ranges are large quantities of excellent timber.

On the headwaters of Price River and on Huntington Creek are extensive beds of coal, and on that portion of the Wasatch Range included in Mr. Renshawe's district are deposits of silver and galena.

Mr. Renshawe extended the secondary triangulation over the whole district assigned him, making stations at an average distance of about ten miles, and measuring all the angles of nearly every triangle in the extension. He also made a connected plane-table map of the whole area, and complemented his work with a complete set of orographic sketches.

The season's work has further demonstrated the value of the orograph and plane-table, and the practical experience has shown them to be well adapted alike to regions of mountains, hills, valleys, plains, and plateaus.

The hypsometric work of this season rests on a primary base established at the general supply and rendezvous camp at Mount Pleasant, and connected by a long series of observations with the station of the United States Signal Service at Salt Lake City. At the base station observations were made with mercurial barometers four times each day, and for eight days during the month hourly from 7 a. m. to 9 p. m. Mercurial barometers were carried by each field party, and observations made to connect every camp with the base station. All the geodetic points and topographic stations were connected by observations with mercurial barometers either with the camps or directly with the base station, or both. All the topographic stations were also connected with each other by angulation, and from these stations the altitudes of all located points were determined by the same method.

The hypsometric work is of the greatest importance, having a direct and practical value in the classification of the lands and the determination of the best methods of utilizing the waters of the streams for irrigation. On account of its practical utility to the agricultural industries of the country, it is believed that more thorough methods should be adopted, and for this purpose it is suggested that a hypsometric base-line be established, extending across the continent, or at least from Lake Michigan to the Pacific Ocean. The railroad lines are now used for this purpose, but their methods of leveling are not deemed of sufficient accuracy for the wants of the work. More refined instruments should be used, more careful work should be done, and the subject should receive careful and thorough discussion. From the base line thus established, lateral lines should be run to the base stations used for each field season by like refined methods.

It is believed that another improvement in this work could be made by the preparation of new tables based upon series of observations made in that portion of the United States where these surveys are conducted. The hypsometric tables now in use are based on observations made at Geneva and Saint Bernard, in Switzerland, points about sixty miles apart, and under climatic conditions greatly different from those obtaining in the Rocky Mountain Region. For this purpose it would be necessary to occupy one or more elevated mountain peaks, with corresponding stations at or near the base, and record hourly observations through a period of one or more years. These stations should be con-

nected by careful leveling, and also connected with the base line above mentioned. The Rocky Mountain Region affords localities better adapted to this purpose than those used in the construction of the present tables.

CARTOGRAPHY.

Much attention has been given to this subject for the purpose of determining the best methods of representing the topography of the region surveyed, taking into consideration the character of the country, the more important facts to be embodied, and the scale adopted for the physical atlas of the Interior Department. The system of cartography in use in this country and many of those in Europe have been examined and studied, and many experiments have been made in the office for the purpose of determining the best methods adapted to these circumstances and conditions. Some of these experiments being now *inchoate*, it is proposed at some future day to give a full account of the same, together with the results reached.

CLASSIFICATION OF LANDS BY MR. GILBERT.

The geographical and geological survey under my direction has been extended over the northern portion of Arizona and the greater part of Utah, but a broad strip along the northern end of the latter Territory was embraced in the survey made by Mr. Clarence King under the War Department. It seemed desirable however to extend the classification of lands over this latter region, and this duty was assigned to Mr. Gilbert.

Mr. Gilbert took the field at Salt Lake City and traversed all of the Territory lying west, north, and northeast of that point, a tract comprising so much of the drainage basin of Great Salt Lake as lies in Utah. In this area is included the most valuable portion of the Territory, as well as one of the most sterile. A very small part of it will repay cultivation without irrigation, but this is exceptional, and in general the possibility of agriculture depends on the possibility of artificial watering. The Bear River and the Jordan carry as much water as can profitably be used upon all the lands to which it is practicable to convey them by canals, and those lands were measured in order to determine the agricultural capacities of the river valleys. The smaller streams, on the contrary, are inadequate to serve the arable lands through which they severally run, and the agricultural capacities of their valleys were ascertained by measuring the volume of each stream. East of Great Salt Lake are great mountain ranges, the Wasatch and the Uinta, and large streams flow from their melting snows all through the summer season. The Bear, the Weber, and the Jordan flow to the lake, and the three rivers can be made to reclaim 800,000 acres of land in their valleys. This is 12½ per cent. of the district which they drain. West of the lake the plains are interrupted by mountains, but there are none of magnitude; the snows of winter are dissipated too early in the spring to be of use for irrigation, and much of the land is an absolute desert. In a total area of 8,300,000 acres only 21,000 acres are of value for farming—one-fourth of one per cent.

These estimates are based upon the experience of the farmers of the district, who have practiced irrigation for thirty years and have given it a greater development than can be found elsewhere in the United States. They have now under cultivation a third part of the irrigable lands of the Salt Lake Basin, and are utilizing many of the small streams to the full extent of their capacities. A careful study was made of their oper-

ations for the purpose of learning the quantity of water necessary to redeem a given quantity of land under various conditions of soil and climate, and the resulting determinations were used in computing the areas susceptible of irrigation by the streams and parts of streams that are still unused. The greater part of the future extension of the cultivated areas will be accomplished only by expensive engineering works, including the damming of the principal rivers and the construction of long canals. Five million dollars is probably a moderate estimate of the cost of redeeming the 500,000 acres that are susceptible of reclamation, and the requisite capital will have to be concentrated upon a small number of large canals.

An investigation was also made of the climate of the district as recorded in the rise and fall of Great Salt Lake. The lake, having no outlet, is filled to higher levels in moist years and shrinks again in dry. No systematic record of its fluctuations has been kept until quite recently, but for the past thirty years the interests and pursuits of settlers upon the shore have been more or less affected by them, and it has proved practicable by gathering the evidence scattered among citizens to elicit the history of the changes. From the year 1847 to the year 1850 the water was constantly at a low stage. A series of five moist seasons then raised its level nearly five feet, and a succeeding series of dry seasons again depressed it, until in 1861 and in 1862 it was as low as when first observed. From that time until 1868 the water rose step by step to its present level, and it has since then continued about ten feet higher than in 1850. About four feet below the present surface there was a beach mark which the lake had not previously covered for many years, or perhaps for centuries, so that the present condition must be regarded as decidedly novel and exceptional. The area of the lake is much greater at its high stage than at its low, and the evaporation from its surface is correspondingly increased. To maintain its present level the inflowing water must be a tenth part greater in amount than it formerly was; and that it is greater is universally testified by those who use the tributary streams for the purpose of irrigation. Whether this increase of streams is due to a transient variation of climate or to the modifications wrought by man upon the face of the country is a question not yet decided; but it may well be doubted whether the agriculturists of Utah should anticipate for the future a climate so favorable as that of the past ten years.

To facilitate the record of the future fluctuations of the lake a number of monuments have been established. At the suggestion of Prof. Joseph Henry, a graduated pillar was placed at the water's edge in 1875 by residents of the Territory, and observations were continued for more than a year. The locality selected has however become inconvenient, and Mr. Gilbert has this year erected a second pillar at a more accessible place. He has moreover established near each of the graduated pillars a permanent stone monument, placed so far above the water as to be in no danger of disturbance by the waves, and these have been connected by spirit-level with the surface of the lake, so as to serve as permanent future reference points.

Mr. Gilbert gave attention also to the timber lands of the same district, investigating their character and extent. They are confined to the higher altitudes, and they form no continuous body of great extent but are scattered in small patches here and there among the mountains.

It will be seen that Mr. Gilbert in performing the special work to which he was assigned, namely, the classification of the lands, has also extended his researches into a broader field embracing climatic changes.

The whole subject is one of prime importance to the industries of the Rocky Mountain Region, as it bears directly upon the agricultural capacity and prospects of the country, and through them on all other industries.

GEOLOGICAL WORK BY MR. GILBERT.

Further observations were made this summer by Mr. Gilbert on recent orographic displacements. It appears that the system of faults and flexures—the system of upward and downward movements—by which the mountain ranges and the valleys of Utah and Nevada were produced have continued down to the present time. Evidence of recent movement has been discovered on the lines of many ancient faults. The ancient shore line of Great Salt Lake which is exhibited so conspicuously upon the surrounding mountain slopes, and which must have originally been level, is no longer so, but has been shifted up and down by the displacement of the mountains. Its present altitude above Great Salt Lake was determined at four different points by spirit-level; and the determinations were found to range from 966 feet to 1,059 feet. The measurements by level were all made in the immediate vicinity of the lake, but the barometer indicates that at points more remote the discrepancy is several times greater.

These observations are valuable additions to our evidence that mountain making is a work of the present as well as of past ages, and that the grand displacement by faults and folds are caused by slow and intermittent movements.

GEOLOGICAL WORK BY CAPTAIN DUTTON.

A geological party was also organized under the direction of Captain Dutton. His supply camp was in Circle Valley, about midway in the course of the Sevier River. The field of labor was through and around the great plateaus drained by this river and its tributaries. In pursuing his investigations he traveled over a large portion of Southern Utah and into Northern Arizona, giving especial attention to the mode of occurrence and the distribution of the eruptive rocks of that region, attention being also given to the borders of the district for the purpose of determining the relation of the extravasated rocks and the underlying sedimentaries. By reason of peculiar geographic conditions the region is one well adapted to successful study. These conditions exist in its great elevations and aridity, giving to the plateaus abruptly escarped edges and causing its water-courses to run in deeply corraded channels or cañons. In this manner the structural geology is revealed to an extent rarely seen in more humid and less elevated regions.

The especial problems for investigation were the relation of extravasated rocks to the sedimentaries, the succession of eruptive beds, and the methods and results of atmospheric degradation. These problems involve many minor ones of importance, and Captain Dutton has returned with a collection of facts that will materially supplement his former work. It is confidently believed that when he has properly arranged and discussed the same, his report will not only be of value for its description of the local geology of the region, but it will also be an important contribution to the general subject of geology.

In addition to geological work the captain has also made an especial study of irrigation within his district, for the purpose of determining the extent of land that can thus be redeemed for agriculture, and the best methods of utilizing the waters of the Sevier and its tributaries.

To this party Mr. J. K. Hillers was attached as photographer, and he

has returned with many views taken in that region, made for the especial purpose of illustrating Captain Dutton's report. These will serve to graphically illustrate many important points in structural geology and the dynamics of degradation.

GEOLOGICAL ILLUSTRATION.

Much attention has been paid to methods of graphically representing the important features of geological structure. The Rocky Mountain Region has proved to be one of great interest in this branch of our investigations, because of the peculiar features of its physical geography. Long and towering escarpments are found, deep cañons with precipitous walls are numerous, its hills and mountains are often without soil and vegetation, accumulations of subaerial or glacial drift are infrequent, and thus the general rock-structure is well revealed. Several new methods of illustration have been devised, some of which have already appeared in the publications of the Survey.

SURVEY OF THE BLACK HILLS.

In 1875 a reconnaissance survey was made of the Black Hills of Dakota by Mr. Walter P. Jenney, with a corps of assistants, under the direction of the honorable Secretary of the Interior. On the return of the party from the field Mr. Jenney's report relating to the mineral resources of the country was immediately published, but the geographical and geological report was unfinished at that time. This latter work was left in the hands of Mr. Henry A. Newton, his geological assistant, to be completed. On May 28, 1877, at the request of Mr. Newton the completion of the work was placed under my direction by order of the honorable Secretary of the Interior.

I was somewhat familiar with the whole subject from the fact that these gentlemen occupied my office during the time in which they were engaged in the preparation of the report.

On consultation with Mr. Newton it appeared wise for him to visit the field again for the purpose of determining certain doubtful points in the geological structure, and to insert on the maps the position of the several towns and roads that have been established in that region since the discovery of gold, and Mr. Newton was employed as a member of my corps, and instructed to proceed to that country for this purpose. He had been in the field but a short time when he was prostrated by the sickness which resulted in his death. Previous to his departure he completed his report on the geology of that country, and the map had been placed in the hands of an engraver; the whole embodying all the facts discovered up to that time. Thus, happily, his work will not be lost. It is expected that his report will be published during the present winter, in the shape in which it was left by him.

The death of Mr. Newton makes a serious break in the ranks of the younger and more active geologists of America. He possessed rare abilities, had had much experience in field operations, and had received thorough and wise training, and his work in other fields had exhibited his ability. But the great work of his short life will doubtless be his report on the geology of the Black Hills of Dakota. It is with sorrow that in thus mentioning his work I am compelled to record the death of an able collaborateur and generous friend.

ETHNOGRAPHIC WORK.

During the field season, while the geographic and geological work was in progress, the ethnographic work was also continued by various

parties and by myself, but as these labors are yet incomplete no further mention of them will here be made.

My own field season was short, and was devoted to correlating the work and to some studies in geology and ethnography.

During the past six years one branch of our work has been considered of paramount importance, namely, the classification of lands and the subjects connected therewith. The object has been to determine the extent of the irrigable lands, timber lands, pasturage lands, coal lands, and mineral lands. In general the lands that are cultivable only through irrigation are limited by the supply of water. There are some exceptions to this. Where streams are found in narrow valleys or run in deep cañons, the limit of agricultural land is determined by the extent of the areas to which the water can be conducted with proper engineering skill. In the study of this subject many interesting and important problems have arisen, and many valuable facts have been collected. As an illustration, I may state, although the computations are not yet complete, that the amount of land that can thus be redeemed by the utilization of the streams, but without the construction of reservoirs, within the Territory of Utah, is about 1,250,000 acres.

From the survey of the timber lands one very important fact appears, that the area where standing timber is actually found is very much smaller than the areas where the conditions of physical geography are such that timber should be found as a spontaneous growth—that is, the *area of timber* is but a small fraction of the *timber region*. The destruction of the timber in such regions now found naked is due to the great fires that so frequently devastate these lands; and the amount of timber taken for economic purposes bears but an exceedingly small ratio to the amount destroyed by fires. Hence the important problem to be solved is the best method by which these fires can be prevented.

Another subject which has received much attention is the utilization of the pasturage-lands; and still another, the best methods of surveying the mineral lands for the purpose of description and identification, that the owners of mines may be relieved of the great burden of litigation to which they are subjected by reason of the inaccurate and expensive methods now in vogue. It is proposed at an early day to submit a report on this subject to the honorable the Secretary of the Interior, presenting the results of our work in the directions above indicated.

Hoping that the labors of the corps under my charge as thus briefly set forth will meet with the approval of the Secretary,

I am, with great respect, your obedient servant,

J. W. POWELL,
In charge U. S. Geog. and Geol. Surv., R. M. R.

The Hon. SECRETARY OF THE INTERIOR,
Washington, D. C.

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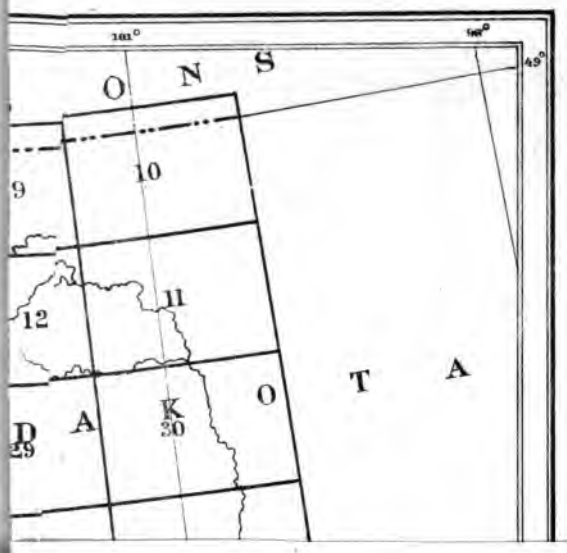
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